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(54) **Carbon resistant surface coating**

Kohlenstoffbeständige Oberflächenschicht

Couche superficielle résistante au carbone

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Description

Background of the Invention

5 [0001] The present invention is related to a coating formulation, for application to mechanical devices or components having surfaces associated with or exposed to combustion and surfaces subjected to elevated temperatures by a chemical grafting technique, to prevent the deposition, at high temperatures, of carbon or coke, which can impact the performance of such devices.

10 [0002] In recent years, carbon deposition has become a serious problem for surfaces associated with combustion, such as fuel injectors, as well as surfaces subjected to elevated temperatures, such as turbine engines and other fuel supply components. This problem can be caused by increased fuel inlet temperatures and a higher compressor air temperatures in, e.g., gas turbines. In high-performance aircraft engines, for instance, the fuel inlet temperature might exceed 177°C (350°F) and the compressor discharge temperature could be as high as 871°C (1,600°F). Under certain operating conditions, the wetted-wall temperature quickly reaches between 204°C (400°F) and 427°C (800°F). Combined with high temperatures and slow velocities, the fuel may undergo chemical degradation, which could lead to the formation of carbon deposits within a short time. Similar deposition problems can occur in automotive applications, power generation, industrial or residential furnaces, and other similar applications.

15 [0003] Once carbon deposits begin to form, they contribute to a number of problems such as reduced fuel flow rate, excessive fuel pressure drop, sticking valves, blocked strainers or filters, and poor spray quality. Any one of these problems could easily affect the overall combustor performance and result in high maintenance costs.

20 [0004] Today's fuel injectors must often operate in a high-temperature environment without carbon formation for long hours. This requirement would be very difficult to meet without significant design improvements. Based on field experience and research studies, certain design guidelines are followed to avoid the flow or surface conditions that facilitate carbon formation. For example, the wetted-wall temperature is usually kept below 107°C (400°F), and the fuel inlet temperature must be lower than 107°C (225°F). Because fuel velocity also plays an important role in determining carbon formation, the flow rate range must be carefully examined. It has been found that carbon formation is most severe for combustors operating under soak back and steady state conditions with flow velocities ranging between 2 and 4 m/s. As fuel velocity exceeds 6 m/s, however, carbon deposition becomes less likely due to effective heat transfer and short resident times.

25 [0005] Despite these guidelines, engineers still have to rely on other design considerations to meet stringent requirements on injector durability and service life. These considerations include pre-stressing the fuel, using fuel additives, applying carbon-resistant coatings, providing better surface finish, adding more effective insulators, using ceramic materials, and implementing passive or active cooling. Based on a literature search and an in-depth study, the use of carbon-resistant coatings on the metal surface appears to be one of the most effective and economical means of reducing carbon formation inside fuel injector passages under adverse temperature environments.

30 [0006] A number of patents describe techniques for preventing the deposition of carbon onto nozzle surfaces. For example, U.S. Patent No. 6,123,273, to Loprenzo, et al., discloses a dual fuel nozzle for inhibiting carbon deposition onto combustible surfaces in a gas turbine, in which the dual fuel nozzles produce an accelerated swirling air flow to preclude impingement of oil spray droplets onto the metal surfaces of the nozzle, and hence prevent carbon deposition thereon. U.S. Patent No. 5,315,822, to Edwards, teaches coating fuel-wetted elements for gas turbines, where the high temperature alloys have a layer of titanium carbide, titanium nitride, titanium boride, or mixtures thereof on them to inhibit a formation of carbon or coke. U.S. Patent No. 5,336,560, to Spence, et al., teaches gas turbine elements which are protected from carbon deposition by the application of a coating of alumina and silica from a sol gel formulated for the purposes of creating an acceptable coating composition. U.S. Patent No. 6,145,763 to Fleming et al. teaches coating automotive fuel injectors with a fluorine-containing amorphous hydrogenated carbon film coating to resist the formation of carbonaceous deposits. This reduction in coking and deposits improves the fuel economy and engine performance.

35 [0007] There are various coating techniques for improving the physical properties of stainless steel and alloy material for carbon resistance. These techniques include thermal spraying, detonation-applied refractory, chemical vapor deposition, and ion implantation. These techniques generally are complicated, expensive, and limited to specific applications.

Summary of the Invention

40 [0008] The present invention is the discovery of a coating formulation for application to surfaces associated with combustion, such as fuel injectors, and surfaces subjected to elevated temperatures, such as fuel supply components, to prevent the deposition at high temperatures of carbon or graphite on such surfaces, such as stainless steel and alloyed steel compositions. The coating formulation forms a thin layer of polymer coating on the surface by chemical grafting involving the use of a graft initiator to create active bonding sites, on the metal surface, for the silicone-based prepolymer to undergo polymerization on the metal surface. The thin layer of polymer coating prevents the deposition at high temperatures, i.e., temperatures up to 371°C (700°F), of carbon or graphite on surfaces such as a stainless steel

or stainless steel alloys. The bonding and polymerization are completed in a single application process without using complex equipment. The coating and process helps surfaces associated with combustion and surfaces subjected to elevated temperature reduce carbon or coke formation and thereby improves the durability and performance of those surfaces.

[0009] The coating is easy to apply, does not add any significant dimensions to the surface, and cannot be easily removed. The coating process does not require expensive equipment or cause any environmental or safety hazards. The coating process can be used for parts or components with complicated configurations. Further, the coating can be used for any surfaces where the surfaces will encounter coking or carbon deposition problems, such as aircraft fuel injectors, automotive fuel injectors, fuel injectors for gas turbine power generators.

Brief Description of the Drawings

[0010]

Fig. #1 is a schematic diagram of the test arrangement for the coking study.

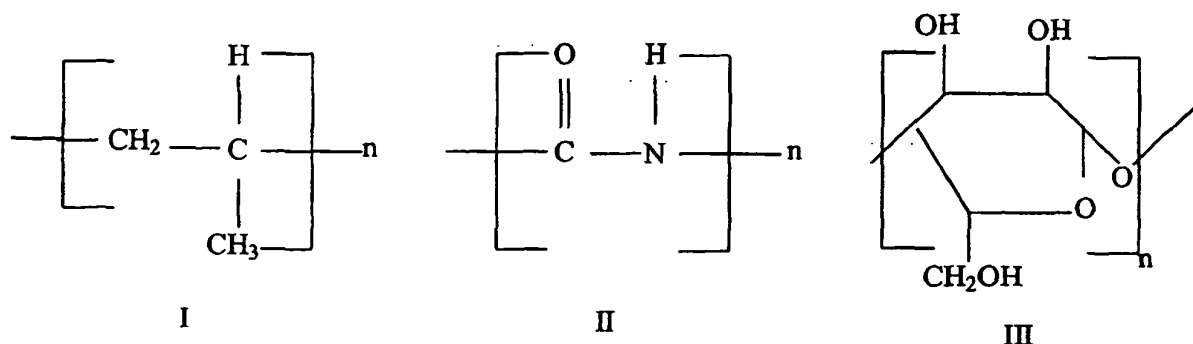
Fig. #2 is a cross-sectional view of the test tube.

Fig. #3 is a photographic comparison between an uncoated sample tube (Fig. 3A) and a coated sample tube (Fig. 3B), both of which were tested at a wall temperature of 315°C (600°F).

Detailed Description of the Invention

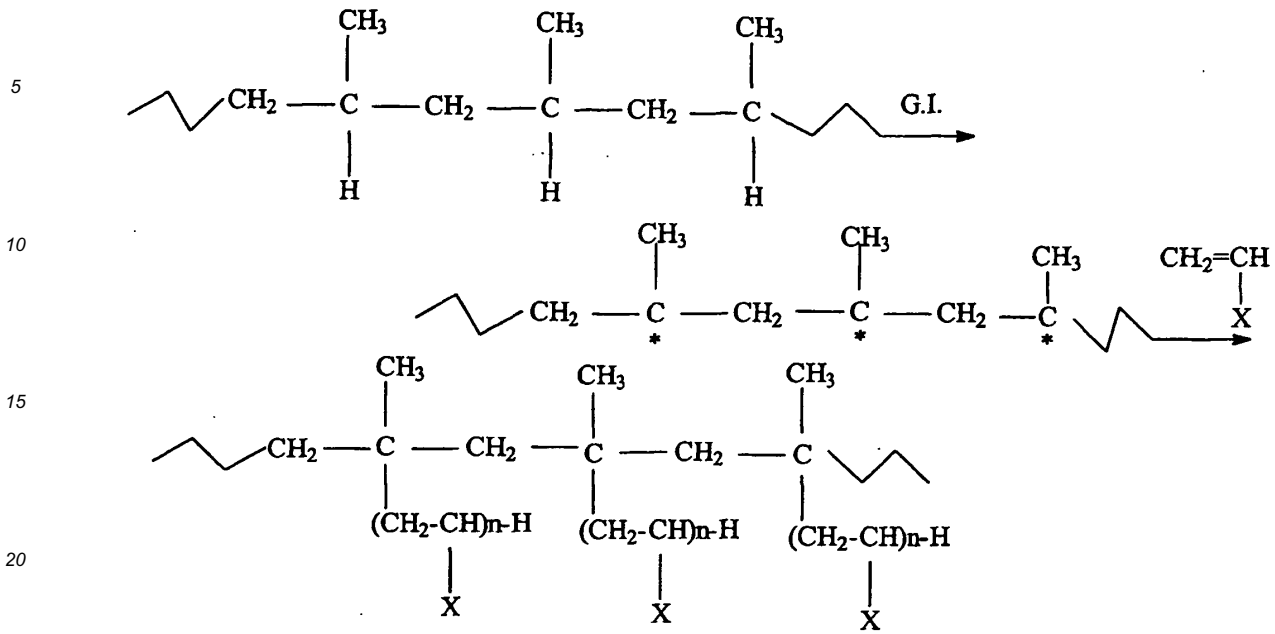
[0011] The coating formulation of the present invention, for application to surfaces associated with combustion and surfaces subjected to elevated temperatures, to prevent the deposition at high temperatures of carbon or graphite on such surfaces, is a silicone-based prepolymer which will undergo polymerization on a metal surface, such as stainless steel or other steel alloys. The coating formulation forms a thin layer of polymer coating on the surface by chemical grafting involving the use of a graft initiator to create active bonding sites, on the metal surface, for the silicone-based prepolymer to undergo polymerization on the metal surface. Alternatively, the silicone-based prepolymer could include minor amounts of a silane monomer and/or a vinyl monomer, such as a (meth)acrylate monomer. The bonding and polymerization are completed in a single application process without using complex equipment. The coating and process helps surfaces associated with combustion and surfaces subjected to elevated temperature reduce carbon or coke formation at temperatures up to 700°F and thereby improves the durability and performance of those surfaces.

[0012] The polymerization process is chemical grafting and it requires the activation of a substrate. Once the substrate has been activated, chains of monomers linked by carbon-carbon bonds grow on the substrate as whiskers. These whiskers impart new properties permanently to the substrate without altering any of the existing characteristics of the base materials. Many materials, both natural and synthetic, contain some form of hydrogen that is more reactive than the "bulk hydrogen". As shown in Formula 1 below, the tertiary hydrogen in polypropylene (I), the amide hydrogen in protein (II), and the hydroxyl hydrogen in polysaccharide (III), are some of those examples.



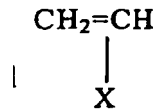
Formula 1

[0013] Certain graft-initiators (G.I.) have the capacity of removing these active hydrogens and concomitantly initiating the growth of polymer chains at the site from where the active hydrogen was removed. In the case of polypropylene, this process can be represented in Formula 2. The * represents a free radical, anion or cation, depending on whether the G.I. removes a hydrogen and one electron, no electrons or two electrons, respectively. Because there are a wide variety of monomers, which do not permit the free-radical type of polymerization, it is beneficial to utilize all three hydrogen mechanisms mentioned above to broaden the scope of application for the current invention.



Formula 2

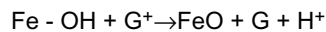
[0014] In Formula 2, the vinyl



35 monomer immediately attaches to the activation sites. "X" represents the new property or properties that are imparted. Under certain circumstances, a mixture of monomers could be employed to impart more than one property onto substrate in a single processing step. These polymer chains whose length can be controlled, are permanently attached to the substrate after curing treatment. The linkage between the graft-polymer and the substrate is covalent. Therefore, the grafted vinyl monomers or prepolymers cannot be easily removed from the substrate.

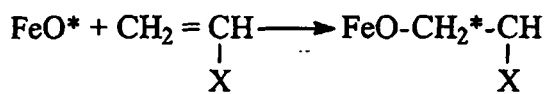
40 [0015] Although the grafting reaction between the metal surface and monomers or prepolymers is thought to involve a reactive species on the steel substrate, the details of the mechanism have not been fully established. In the presence of moisture, there is a layer of oxide and hydroxyl groups tenaciously bound to the steel substrate. The hydrogen of the hydroxyl group may be removed by the graft initiator and form a radical which reacts with the monomer starting graft polymerization. The oxides and hydroxyl groups react with epoxy groups of the prepolymers or monomers initiating a chemical reaction that also leads to a strong bonding between the alloy and organic polymer formed on the surface.

45 [0016] The mechanism of graft polymerization for metal surface may be described in the steps shown in Formula 3. The process of termination may differ when the formulation contains reactive prepolymers or polymers. The prepolymers may also undergo activation by the graft initiator generating reactive radicals P^* , which react with the radical on the steel surface forming a graft coating on the substrate. This process is illustrated in Formula 4.



Radical (1)

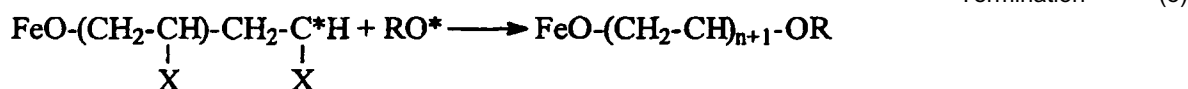
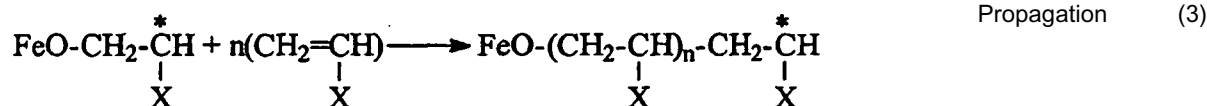
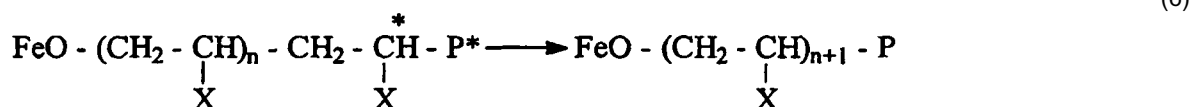
Formation



Graft (2)

Initialisation

(continued)

**Formula 3****Formula 4**

[0017] The graft initiator G may consist of the following metal ions: Fe⁺⁺⁺, Fe⁺⁺, Ag⁺, Co⁺⁺, Ni⁺⁺, Ce⁺⁺⁺ and Cu⁺⁺. The peroxide may be chosen from catalysts such as benzoyl peroxide, methyl ethyl ketone peroxide, tert butyl hydroperoxide and hydrogen peroxide. The monomers and prepolymers have side functional groups X, which may react between themselves and with additional prepolymers or polymers included onto the formulation forming a cross-linked organic coating. The functional groups of the monomers and prepolymers should consist of hydroxyl groups, carbonyl groups, secondary and/or tertiary amino groups and epoxy groups. The molecular ratio of the functional groups of the reactive components are chosen so that no free groups are left after the reaction is completed.

[0018] A pre-calculated quantity of silicone prepolymer Silikophen 80/20 was prepared in a container. Then, the other ingredients were added in the proper ratio and sequence as described in the sample formulations. The contents were stirred to a uniform solution. The concentration of the ingredients was measured by weight. Examples of the formulations are presented in Table I.

Table I

Item	Description of Ingredient	Example 1 (Grams)	Example 2 (Grams)	Example 3 (Grams)	Example 4 (Grams)
1	Silikophen P80/20 Silicone Prepolymer	600	100	100	72
2	GE SR125 Silicone Prepolymer	600	900	---	---
3	GE SR112 Silicone Prepolymer	---	---	900	840
4	Methyl Ethyl Ketone Solvent	600	600	600	544
5	Xylene Solvent	540	400	400	368
6	Cellosolve Acetate Solvent	500	300	300	280
7	Bentone SD2 Additive	10	10	10	6
8	Troymax 8% Zinc	2	4	4	4

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(continued)

Item	Description of Ingredient	Example 1 (Grams)	Example 2 (Grams)	Example 3 (Grams)	Example 4 (Grams)
9	A1100 Silane Monomer	0.1	0.1	0.1	0.1
10	Hexafluoro Butyl Methacrylate Monomer	0.01	0.01	---	---
11	Trifluoro Ethyl Methacrylate Monomer	---	---	0.01	0.01
12	Benzoyl Peroxide Graft Initiator	0.001	0.001	0.001	0.001

Table II

Ingredients	
Ingredient	Manufacturer
Silikophen P80/20 Silicone Prepolymer is a Polysiloxane Resin	Goldschmidt Chemical Corporation
GE SR125 Silicone Prepolymer is a methylphenylpolysiloxane solution	GE Silicones
GE SR112 Silicone Prepolymer is a methylphenylpolysiloxane solution	GE Silicones
Methyl Ethyl Ketone Solvent	Shell Oil Company
Xylene Solvent is an aromatic hydrocarbon solvent	CITGO Petroleum Corporation
Cellosolve Acetate Solvent is a propylene glycol monomethyl ether acetate	Eastman Chemical Company
Bentone SD2 Additive is a rheological additive	Rheox Inc.
Troymax 8% Zinc is a Zinc Alkanoate Catalyst	Troy Chemical
Silane Monomer A1100 is a gamma- Aminopropyltriethoxysilane	Witco Corporation
Hexafluoro Butyl Methacrylate Monomer	Aldrich Chemical
Trifluoro Ethyl Methacrylate Monomer is a 2,2,2-Trifluoroethyl 2-Propenoic Acid Ester	Monomer-Polymer and Dajac Laboratories, Inc.
Benzoyl Peroxide Graft Initiator	Dajac Laboratories, Inc.

[0019] The coating formulation can be applied onto the metal surface in a number of different ways. It is important that the surface to which the coating will be applied be as clean as possible. It should have no grease or oil on the surface which could interfere with the chemical grafting. Preferably it is applied by having all the ingredients mixed together. For example, the polysiloxane polymer can be applied to the surface as a liquid formulation containing a mixture of polysiloxane or silicone prepolymer, a silane monomer, a vinyl monomer such as a (meth)acrylate monomer, a graft initiator, a catalyst, a solvent, and additives. Further, other polysiloxane prepolymers could be employed such as GE SR 940 silicones or Dow Corning 804 silicones. The additives could include those compositions normally added to coating compositions to adjust their performance or control the rheology of the coating formulation, such as thickeners, fillers, leveling agents, wetting agents, defoamers, and the like. There is no criticality in the selection of the solvent employed nor in the combination of solvents or the ratio of the solvents when used as a combination of solvents. Typically, a combination of solvents proves to be the most effective, but the coating should work with a single solvent. Convenient methods for applying the coating composition are dipping, spraying and pumping. For inside walls of the fuel injector, coating solution is forced through the passages by a MasterFlex liquid pump. In order to drain the excessive formulation, the injector passage needs to be purged by compressed air.

[0020] The coated injector was then cured in the oven at 100°C for 30 minutes followed by a final cure at 225°C for one hour. After one and one-half hour in the oven, the injector is removed allowing it to cool down to ambient temperature. The curing conditions are not critical, although the two step cure is preferred. The precise conditions will depend upon the prepolymers and/or monomers employed, but it is expected that the curing will be done at a temperature range of 85°C to 300°C, with a range of 100°C to 225°C being preferred, for a period of 1 to 3 hours duration.

[0021] In order to demonstrate the utility of the coatings in accordance with the present invention, a laboratory test rig, which is shown in Fig. 1, was set up to conduct an evaluation of coating compositions Example 1 and 2, which are set forth in Table I. It was devised to simulate the typical fuel flow conditions inside fuel injectors using straight tubes. The test tube is shown in cross-section in Figure 2.

[0022] The test tube 1 has a straight center section 2, enlarged end sections 3 and 4 to facilitate placement in a heated copper cylinder 10, and connections to lines feeding fuel into and out of the test tube. The enlarged ends 3 and 4 comprise openings 5 and 6 for connecting to the inlet and outlet lines, and a transitional section 7 and 8 which are in communication with the central heated region 2 of the test tube 9. The copper cylinder 10, for the purpose of the test, comprised a central section 9 having a thickness of 0.25" and end sections having a thickness of 1.0". The center section of the cylinder 9 had a hole with a diameter of 0.0625".

[0023] As seen in Figure 1, the tube 1 is inserted into the copper cylinder 10, which is wrapped around by the band heater 11, the band heater is in turn surrounded by insulation 12. Fuel is fed to the test setup from a fuel supply tank 13. The fuel is pumped by a pump 14. To insure that particulate matter does not reach the test cylinder, fuel filters 15 and 16 are placed ahead of and after the fuel pump 14. To facilitate an even flow of fuel, an accumulator 17 is placed in the fuel line. To control the fuel temperature, the fuel passes through a fuel pre-heater 18 before entering the test tube via line 19. A temperature controller 20 is employed to set the fuel and tube wall temperatures. The fuel, after passing through the test tube 1, exits via line 21 and passes through a heat exchanger 22 to reduce the temperature of the exit fuel, which passes to waste tank 23. Pressure gauge 24 and pressure regulator 25 are used to regulate the line pressure to prevent two-phase flow from occurring.

[0024] Only the central 0.300-inch section of the test tube 1, as shown in Figure 2, is directly in contact with the heating cylinder 10. Three thermocouples (not shown) were embedded between the cylinder 10 and the exterior of the tube surface 1 for monitoring and controlling of the wall temperature. The wall temperature was set at 315°C (600°F), and the fuel volume flow rate was maintained at 20 cc/min. The fuel inlet temperature was in the 160 to 177°C (320 to 350°F) range. Jet-A fuel was used in all of the tests, and it was not recirculated through the apparatus.

[0025] After each test, the test tube was sliced in half along its axis to expose the interior wall surface, allowing a detailed analysis of the deposits. Quantitative deposit analyses were conducted using an Elemental Analyzer to measure the amount of deposits. Visual and photographic methods were also used to provide a qualitative comparison of the coating performance and deposit results. The coatings in Examples 1 and 2 were applied to four different stainless steel materials, namely 316ss, 410ss, 440Css, and 17-4PH.

[0026] All the tests were conducted using a wall temperature of 315°C (600°F), a fuel flow rate of 20 cc/min, a fuel inlet temperature of 160°C (320°F), and a test duration of 40 hours. The surface finish of the tubes was estimated to be 8,128 μm (32 micro-inches). The test results summarized in Table III show that the coating of Example 2 resulted in better performance with no deposits.

Table III

Test No.	Material Type	Coating Example No.	Visual Result
1	440C	None	Heavy deposits
2	410	None	Medium deposits
3	316	None	No deposits
4	316	2	No deposits
5	440C	1	Little to no deposits
6	440C	2	Little to no deposits
7	410	1	Heavy deposits
8	410	2	No deposits
9	17-4PH	1	No deposits
10	440C	2	No deposits
11	410	2	No deposits

[0027] Additional tests were made using the composition of Example 2 on a variety of additional compositions, including 410ss, IN625, IN718, HAST-X, 347ss, 17-4PH, 440C, 440F, and Greek Ascology, and the results are shown in Table IV. The surface finish on the tubes was estimated to be 50,8 μm (200 micro-inches). The tests were conducted using a fuel flow of 20 cc/min, a wall temperature of 160°C (600°F), fuel inlet temperatures of 177°C (350°F), and a test duration of 40 hours. The results summarized in Table IV indicate that the nickel-based alloys appear to be more compatible with the present formulations and showed the most reduction in carbon formation. Further, the results in Table IV show that, at a higher fuel inlet temperature and a coarser surface finish, the coating of the present invention provides greater protection against coking as compared to uncoated surfaces. The results also show that, while no single formulation is compatible for all the stainless steel alloys and that the chemical composition of the alloys has a strong influence on the effectiveness of the coating, the composition of the present invention significantly reduces carbon build-up. As noted, the surface finish or texture of the substrate appears to play an important role in determining the results of the coating formulation. Generally, the finer the surface finish, the better the coating performance. Thus, it is desirable that the surface finish be maintained at no more than 76,2 μm (300 micro-inches), preferably less, with no more than 8,128 μm (32 micro-inches) being preferred.

Table IV

Test No.	Material Type	Coating Example No.	Test Result
12	316	2	Medium Deposits
13	HAST-X	2	Light deposits
14	347	2	Light deposits
15	440C	2	Medium deposits
16	410	2	No deposits
17	17-4PH	2	Light deposits
18	440F	2	Heavy deposits
19	IN625	2	No deposits
20	IN718	2	No deposits
21	GR-ASC	2	Medium deposits
22	316	None	Heavy deposits
23	440C	None	Heavy deposits
24	410	None	Heavy deposits

[0028] Photograph Fig. 3 shows a comparison of carbon formation between an uncoated 410ss sample tube and a tube coated with the composition of Example 2. This is a visual of the test result comparing an uncoated 410 stainless steel tube (Test 2) against a 410 stainless steel tube coated with the composition of Example 2 (Test 11). As can be seen in the photos in Fig. 3, the uncoated sample tube resulted in significant deposits of carbon, while the coated tube shows no deposits of carbon. The interior wall of the coated tube only exhibits a slight change of color due to heating.

[0029] The coating compositions of Examples 3 and 4 also were evaluated by applying them to the inside of tubes, similar to those describe in the tests involving Examples 1 and 2. The coated tubes were then evaluated against an uncoated tube by flushing the inside of the tube with fuel and then putting the tube in a test oven for thirty minutes at 204°C (400°F). This was repeated, i.e., the flushing and heating in a oven cycle, for about 80 hours. After that, the tube was sliced in half and visually inspected. Carbon was found to have built up on the uncoated tube, while none was found on the coated tubes, although the coating showed a slight change in coloring due to the heating.

Claims

1. A deposit-resistant fuel-supply or injection component, comprising said component having a coating on at least one metal-containing and/or metal surface thereof to prevent carbon or coke formation at high temperatures, said coating comprising a polysiloxane polymer which is graft polymerized to the metal-containing and/or metal surface of the component to thereby resist deposit of carbon or coke.

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2. The component of claim 1 wherein the polysiloxane polymer is a methylphenylpolysiloxane polymer.
3. The component of claim 1 wherein the polysiloxane polymer is applied to the metal-containing and/or metal surface as a solution.
- 5 4. The component of claim 1 wherein the polysiloxane polymer is applied to the metal-containing and/or metal surface as a solution of a polysiloxane prepolymer, a silane monomer and a vinyl monomer.
- 10 5. The component of claim 1 wherein the polysiloxane polymer is applied to the metal-containing and/or metal surface as a liquid formulation containing a mixture of siloxane prepolymer, a graft initiator, and a catalyst.
6. The component of claim 1 wherein the metal-containing and/or metal surface is a stainless steel or a stainless steel alloy.
- 15 7. The component of claim 1 wherein the coating is effective at temperatures from 148,9 °C (300 °F) to 371 °C (700 °F).
8. The component of claim 1 wherein the polymer coating is 12,7 μm (0.0005 inch) to 76,2 μm (0.003 inch) thick.
- 20 9. The component of claim 1 wherein the graft polymerization is initiated by a metal ion selected from the group consisting of Fe⁺⁺⁺, Fe⁺⁺, Ag⁺, Co⁺⁺, Ni⁺⁺, Ce⁺⁺⁺, and Cu⁺⁺.
10. The component of claim 1 wherein the polysiloxane polymer is applied to the metal-containing and/or metal surface as a liquid formulation containing a mixture of siloxane prepolymer, a silane, a vinyl monomer, a graft initiator, a catalyst, a solvent, and additives.
- 25 11. The component of claim 1 wherein said polysiloxane polymer is obtained by polymerizing a polysiloxane prepolymer with minor amounts of a silane monomer and a vinyl monomer.
12. The component of claim 4 wherein the vinyl monomer is selected from the group consisting of hexafluoro-butyl methacrylate monomer and trifluoro-ethyl methacrylate monomer.
- 30 13. A method of forming a thin layer of polymer coating on a metal-containing and/or metal surface to prevent carbon or coke formation at high temperatures comprising:
 - 35 (a) applying to the surface a graft initiator having the capability of removing an active hydrogen in the hydroxyl metal group of the metal-containing and/or metal surface;
 - (b) forming a bonding site;
 - (c) applying a polysiloxane prepolymer to the metal-containing and/or metal surface to react the bonding site with the reactive groups of the prepolymers; and
 - 40 (d) polymerizing said prepolymer to provide a metal-containing and/or metal surface coating on said metal-containing and/or metal surface whereby carbon and/or coke are prevented from forming.
14. The method of claim 13, wherein the metal-containing and/or metal surface is a stainless steel alloy.
- 45 15. The method of claim 13, wherein said bonding and polymerization are completed in a single application step.
16. The method of claim 13, wherein said coating is applied by pumping, brushing, or spraying the mixture onto the exterior and/or interior surfaces of the item to be coated.
- 50 17. The coating method of claim 13, wherein the graft initiator is selected from the group consisting of Fe⁺⁺⁺, Fe⁺⁺, Ag⁺, Co⁺⁺, Ni⁺⁺, Ce⁺⁺⁺, and Cu⁺⁺ metal ions.
18. The coating method of claim 13, wherein the prepolymer further includes a peroxide is selected from the group consisting of benzyl peroxide, methyl ethyl ketone peroxide, tert-butyl hydroperoxide, and hydrogen peroxide.
- 55 19. The coating method of claim 13, wherein the prepolymer is a polysiloxane resin.
20. The coating method of claim 13, wherein the prepolymers contain functional groups selected from the ground

consisting of hydroxyl groups, carbonyl groups, secondary and/or tertiary amino groups, and epoxy groups.

- 5
21. The coating method of claim 13, wherein the ratio of functional groups is selected so that no free radical groups are left after the reaction is completed.
22. The coating method of claim 13, wherein the polysiloxane prepolymer is applied to the metal-containing and/or metal surface as a solution.
- 10
23. The coating method of claim 13, wherein the polysiloxane prepolymer is applied to the metal-containing and/or metal surface as a solution of a polysiloxane prepolymer, a silane monomer and a vinyl monomer.
24. The coating method of claim 13, wherein the polysiloxane prepolymer is applied to the metal-containing and/or metal surface as a liquid formulation containing a mixture of siloxane prepolymer, a silane monomer, a vinyl monomer, a graft initiator, and a catalyst.
- 15
25. The coating method of claim 13, wherein the coating is effective at temperatures from 148,9 °C (300°F) to 371 °C (700°F).
26. The coating method of claim 13, wherein the polymer coating is 2,54 μm (0.0001 inch) to 25,4 μm (0.010 inch) thick.
- 20
27. The coating method of claim 13, wherein the polymer coating is 12,7 μm (0.0005 inch) to 76,2 μm (0.003 inch) thick.
28. The coating method of claim 13, wherein the coating is subsequently air dried and heated to a temperature of 85 °C to 300 °C for 1 to 3 hours.
- 25
29. The coating method of claim 13, wherein the coating is subsequently air dried and heated to a temperature of 100 °C for 30 minutes, followed by a second heating at 225 °C for 1 hour.
- 30
30. The coating method of claim 13, wherein the coating is subsequently air dried and heated to a temperature of 100 °C to 225 °C for 1 to 3 hours.
31. The coating method of claim 13, wherein the vinyl monomer is selected from the group consisting of hexafluorobutyl methacrylate monomer and trifluoro-ethyl methacrylate monomer.

35

Patentansprüche

- 40
1. Belagabweisende Kraftstoffzufuhrkomponente oder Kraftstoffeinspritzkomponente, umfassend die Komponente mit einer Beschichtung auf wenigstens einer metallhaltigen und/oder Metallfläche davon, um eine Kohlenstoff- oder Koksbildung bei hohen Temperaturen zu verhindern, wobei die Beschichtung ein Polysiloxanpolymer umfasst, das an die metallhaltige und/oder Metallfläche der Komponente pfpfopolymerisiert wird, damit diese einer Abscheidung von Kohlenstoff oder Koks widersteht.
- 45
2. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer ein Methylphenylpolysiloxan-Polymer ist.
3. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer als Lösung auf die metallhaltige und/oder Metallfläche aufgetragen wird.
- 50
4. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer als Lösung eines Polysiloxan-Prepolymers, eines Silanmonomers und eines Vinylmonomers auf die metallhaltige und/oder Metallfläche aufgetragen wird.
- 55
5. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer als flüssige Formulierung, die eine Mischung aus einem Siloxan-Prepolymer, einem Pfpfinitiator und einem Katalysator enthält, auf die metallhaltige und/oder Metallfläche aufgetragen wird.
6. Komponente nach Anspruch 1, wobei die metallhaltige und/oder Metallfläche ein rostfreier Stahl oder eine rostfreie Stahllegierung ist.

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7. Komponente nach Anspruch 1, wobei die Beschichtung bei Temperaturen von 148,9 °C (300 °F) bis 371 °C (700 °F) wirksam ist.
- 5 8. Komponente nach Anspruch 1, wobei die Polymerbeschichtung 12,7 µm (0,0005 inch) bis 76,2 µm (0,003 inch) dick ist.
9. Komponente nach Anspruch 1, wobei die Pflropfpolymerisation durch ein Metallion initiiert wird, das aus der aus Fe⁺⁺⁺, Fe⁺⁺, Ag⁺, Co⁺⁺, Ni⁺⁺, Ce⁺⁺⁺ und Cu⁺⁺ bestehenden Gruppe ausgewählt ist.
- 10 10. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer als flüssige Formulierung, die eine Mischung aus einem Siloxan-Prepolymer, einem Silan, einem Vinylmonomer, einem Pflropfinitiator, einem Katalysator, einem Lösungsmittel und Additiven enthält, auf die metallhaltige und/oder Metallfläche aufgetragen wird.
- 15 11. Komponente nach Anspruch 1, wobei das Polysiloxanpolymer durch die Polymerisation eines Polysiloxan-Prepolymers mit kleineren Mengen eines Silanmonomers und eines Vinylmonomers erhalten wird.
12. Komponente nach Anspruch 4, wobei das Vinylmonomer aus der aus Hexafluorbutylmethacrylat-Monomer und Trifluorethylmethacrylat-Monomer bestehenden Gruppe ausgewählt ist.
- 20 13. Verfahren zur Bildung einer dünnen Schicht aus einer Polymerbeschichtung auf einer metallhaltigen und/oder Metallfläche, um eine Kohlenstoff- oder Koksbildung bei hohen Temperaturen zu verhindern, umfassend:
- (a) Auftragen eines Pflropfinitiators auf die Oberfläche, der die Fähigkeit zur Entfernung eines aktiven Wasserstoffs in der Hydroxylmetallgruppe der metallhaltigen und/oder Metallfläche hat;
- 25 (b) Bilden einer Bindungsstelle;
- (c) Auftragen eines Polysiloxan-Prepolymers auf die metallhaltige und/oder Metallfläche, um die Bindungsstelle mit den reaktiven Gruppen der Prepolymere umzusetzen, und
- (d) Polymerisieren des Prepolymers unter Erhalt einer metallhaltigen und/oder Metallflächenbeschichtung auf der metallhaltigen und/oder Metallfläche, wodurch eine Bildung von Kohlenstoff und/oder Koks verhindert wird.
- 30 14. Verfahren nach Anspruch 13, wobei die metallhaltige und/oder Metallfläche eine rostfreie Stahllegierung ist.
15. Verfahren nach Anspruch 13, wobei das Binden und die Polymerisation in einem einzigen Auftragungsschritt vervollständigt werden.
- 35 16. Verfahren nach Anspruch 13, wobei die Beschichtung durch Pumpen, Pinseln oder Spritzen der Mischung auf die Außen- und/oder Innenflächen des zu beschichtenden Teils aufgetragen wird.
17. Beschichtungsverfahren nach Anspruch 13, wobei der Pflropfinitiator aus der aus Fe⁺⁺⁺-, Fe⁺⁺-, Ag⁺-, Co⁺⁺-, Ni⁺⁺-, Ce⁺⁺⁺- und Cu⁺⁺-Metallionen bestehenden Gruppe ausgewählt ist.
- 40 18. Beschichtungsverfahren nach Anspruch 13, wobei das Prepolymer weiterhin ein Peroxid einschließt, das aus der aus Benzylperoxid, Methyläthylketonperoxid, tert-Butylhydroperoxid und Wasserstoffperoxid bestehenden Gruppe ausgewählt ist.
- 45 19. Beschichtungsverfahren nach Anspruch 13, wobei das Prepolymer ein Polysiloxanharz ist.
20. Beschichtungsverfahren nach Anspruch 13, wobei die Prepolymere funktionelle Gruppen enthalten, die aus der aus Hydroxylgruppen, Carbonylgruppen, sekundären und/oder tertiären Aminogruppen und Epoxygruppen bestehenden Gruppe ausgewählt sind.
- 50 21. Beschichtungsverfahren nach Anspruch 13, wobei das Verhältnis der funktionellen Gruppen so ausgewählt ist, dass keine freien radikalischen Gruppen verbleiben, nachdem die Reaktion abgeschlossen ist.
- 55 22. Beschichtungsverfahren nach Anspruch 13, wobei das Polysiloxan-Prepolymer als Lösung auf die metallhaltige und/oder Metallfläche aufgetragen wird.
23. Beschichtungsverfahren nach Anspruch 13, wobei das Polysiloxan-Prepolymer als Lösung eines Polysiloxan-Pre-

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polymers, eines Silanmonomers und eines Vinylmonomers auf die metallhaltige und/oder Metallfläche aufgetragen wird.

5 24. Beschichtungsverfahren nach Anspruch 13, wobei das Polysiloxan-Prepolymer als flüssige Formulierung, die eine Mischung aus einem Siloxan-Prepolymer, einem Silanmonomer, einem Vinylmonomer, einem Pfpfropfinitiator und einem Katalysator enthält, auf die metallhaltige und/oder Metallfläche aufgetragen wird.

10 25. Beschichtungsverfahren nach Anspruch 13, wobei die Beschichtung bei Temperaturen von 148,9 °C (300 °F) bis 371 °C (700 °F) wirksam ist.

26. Beschichtungsverfahren nach Anspruch 13, wobei die Polymerbeschichtung 2,54 µm (0,0001 inch) bis 25,4 µm (0,010 inch) dick ist.

15 27. Beschichtungsverfahren nach Anspruch 13, wobei die Polymerbeschichtung 12,7 µm (0,0005 inch) bis 76,2 µm (0,003 inch) dick ist.

28. Beschichtungsverfahren nach Anspruch 13, wobei die Beschichtung anschließend luftgetrocknet und 1 bis 3 h lang auf eine Temperatur von 85 °C bis 300 °C erwärmt wird.

20 29. Beschichtungsverfahren nach Anspruch 13, wobei die Beschichtung luftgetrocknet und 30 min lang auf eine Temperatur von 100 °C erwärmt wird, gefolgt von einem zweiten, 1-stündigen Erwärmen bei 225 °C.

25 30. Beschichtungsverfahren nach Anspruch 13, wobei die Beschichtung anschließend luftgetrocknet und 1 bis 3 h lang auf eine Temperatur von 100 °C bis 225 °C erwärmt wird.

31. Beschichtungsverfahren nach Anspruch 13, wobei das Vinylmonomer aus der aus Hexafluorbutylmethacrylat-Monomer und Trifluorethylmethacrylat-Monomer bestehenden Gruppe ausgewählt ist.

30 Revendications

35 1. Composant d'alimentation ou d'injection de carburant résistant au dépôt, comprenant ledit composant ayant un revêtement sur au moins une surface contenant un métal et/ou en métal de celui-ci pour empêcher la formation de carbone ou de coke aux hautes températures, ledit revêtement comprenant un polymère poly(siloxane) qui est polymérisé par greffage sur la surface contenant un métal et/ou en métal du composant pour résister ainsi au dépôt de carbone ou de coke.

40 2. Composant selon la revendication 1, dans lequel le polymère poly(siloxane) est un polymère méthylphénylpoly(siloxane).

3. Composant selon la revendication 1, dans lequel le polymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme d'une solution.

45 4. Composant selon la revendication 1, dans lequel le polymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme d'une solution d'un prépolymère poly(siloxane), d'un monomère de silane et d'un monomère de vinyle.

50 5. Composant selon la revendication 1, dans lequel le polymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme d'une formulation liquide contenant un mélange de prépolymère de siloxane, d'un initiateur de greffage et d'un catalyseur.

6. Composant selon la revendication 1, dans lequel la surface contenant un métal et/ou en métal est un acier inoxydable ou un alliage d'acier inoxydable.

55 7. Composant selon la revendication 1, dans lequel le revêtement est efficace à des températures de 148,9 °C (300 °F) à 371 °C (700 °F).

8. Composant selon la revendication 1, dans lequel le revêtement polymère est épais de 12,7 µm (0,0005 pouce) à

76,2 μm (0,003 pouce).

- 5
9. Composant selon la revendication 1, dans lequel la polymérisation par greffage est initiée par un ion métallique choisi dans le groupe constitué par Fe^{+++} , Fe^{++} , Ag^+ , Co^{++} , Ni^{++} , Ce^{+++} et Cu^{++} .
10. Composant selon la revendication 1, dans lequel le polymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme d'une formulation liquide contenant un mélange de prépolymère de siloxane, d'un silane, d'un monomère de vinyle, d'un initiateur de greffage, d'un catalyseur, d'un solvant et d'additifs.
- 10
11. Composant selon la revendication 1, dans lequel ledit polymère poly(siloxane) est obtenu en polymérisant un prépolymère poly(siloxane) avec des quantités mineures d'un monomère de silane et d'un monomère de vinyle.
12. Composant selon la revendication 4, dans lequel le monomère de vinyle est choisi dans le groupe constitué par le monomère méthacrylate d'hexafluorobutyle et le monomère méthacrylate de trifluoroéthyle.
- 15
13. Procédé de formation d'une couche mince de revêtement polymère sur une surface contenant un métal et/ou en métal pour empêcher la formation de carbone ou de coke aux hautes températures, comprenant les étapes consistant à :
- 20
- (a) appliquer sur la surface un initiateur de greffage ayant la capacité d'éliminer un hydrogène actif dans le groupe hydroxyl métal de la surface contenant un métal et/ou en métal ;
- (b) former un site de liaison ;
- (c) appliquer un prépolymère poly(siloxane) sur la surface contenant un métal et/ou en métal pour faire réagir le site de liaison avec les groupes réactifs des prépolymères ; et
- 25
- (d) polymériser ledit prépolymère pour former un revêtement de surface contenant un métal et/ou en métal sur ladite surface contenant un métal et/ou en métal moyennant quoi le carbone et/ou le coke sont empêchés de se former.
- 30
14. Procédé selon la revendication 13, dans lequel la surface contenant un métal et/ou en métal est un alliage d'acier inoxydable.
15. Procédé selon la revendication 13, dans lequel ladite liaison et ladite polymérisation sont achevées en une étape d'application unique.
- 35
16. Procédé selon la revendication 13, dans lequel ledit revêtement est appliqué par pompage, brossage ou pulvérisation du mélange sur les surfaces extérieures et/ou intérieures de l'article devant être revêtu.
17. Procédé de revêtement selon la revendication 13, dans lequel l'initiateur de greffage est choisi dans le groupe constitué par les ions métalliques Fe^{+++} , Fe^{++} , Ag^+ , Co^{++} , Ni^{++} , Ce^{+++} et Cu^{++} .
- 40
18. Procédé de revêtement selon la revendication 13, dans lequel le prépolymère comprend en outre un peroxyde qui est choisi dans le groupe constitué par le peroxyde de benzyle, le peroxyde de méthyl éthyl cétone, l'hydroperoxyde de tert-butyle et le peroxyde d'hydrogène.
- 45
19. Procédé de revêtement selon la revendication 13, dans lequel le prépolymère est une résine poly(siloxane).
20. Procédé de revêtement selon la revendication 13, dans lequel les prépolymères contiennent des groupes fonctionnels choisis dans le groupe constitué par les groupes hydroxyle, les groupes carbonyle, les groupes amino secondaires et/ou tertiaires et les groupes époxy.
- 50
21. Procédé de revêtement selon la revendication 13, dans lequel le rapport des groupes fonctionnels est choisi de sorte qu'aucun groupe radicalaire libre n'est laissé après que la réaction est achevée.
- 55
22. Procédé de revêtement selon la revendication 13, dans lequel le prépolymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme de solution.
23. Procédé de revêtement selon la revendication 13, dans lequel le prépolymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme de solution d'un prépolymère poly(siloxane), d'un monomère

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de silane et d'un monomère de vinyle.

- 5
24. Procédé de revêtement selon la revendication 13, dans lequel le prépolymère poly(siloxane) est appliqué sur la surface contenant un métal et/ou en métal sous forme de formulation liquide contenant un mélange de prépolymère de siloxane, d'un monomère de silane, d'un monomère de vinyle, d'un initiateur de greffage et d'un catalyseur.
- 10
25. Procédé de revêtement selon la revendication 13, dans lequel le revêtement est efficace aux températures de 148,9 °C (300 °F) à 371 °C (700 °F).
- 15
26. Procédé de revêtement selon la revendication 13, dans lequel le revêtement polymère est épais de 2,54 µm (0,0001 pouce) à 25,4 µm (0,010 pouce).
27. Procédé de revêtement selon la revendication 13, dans lequel le revêtement polymère est épais de 12,7 µm (0,0005 pouce) à 76,2 µm (0,003 pouce).
- 20
28. Procédé de revêtement selon la revendication 13, dans lequel le revêtement est ultérieurement séché à l'air et chauffé à une température de 85 °C à 300 °C pendant 1 à 3 heures.
- 25
29. Procédé de revêtement selon la revendication 13, dans lequel le revêtement est ultérieurement séché à l'air et chauffé à une température de 100 °C pendant 30 minutes, suivi par un second chauffage à 225 °C pendant 1 heure.
- 30
30. Procédé de revêtement selon la revendication 13, dans lequel le revêtement est ultérieurement séché à l'air et chauffé à une température de 100 °C à 225 °C pendant 1 à 3 heures.
- 35
31. Procédé de revêtement selon la revendication 13, dans lequel le monomère de vinyle est choisi dans le groupe constitué par le monomère méthacrylate d'hexafluorobutyle et le monomère méthacrylate de trifluoroéthyle.
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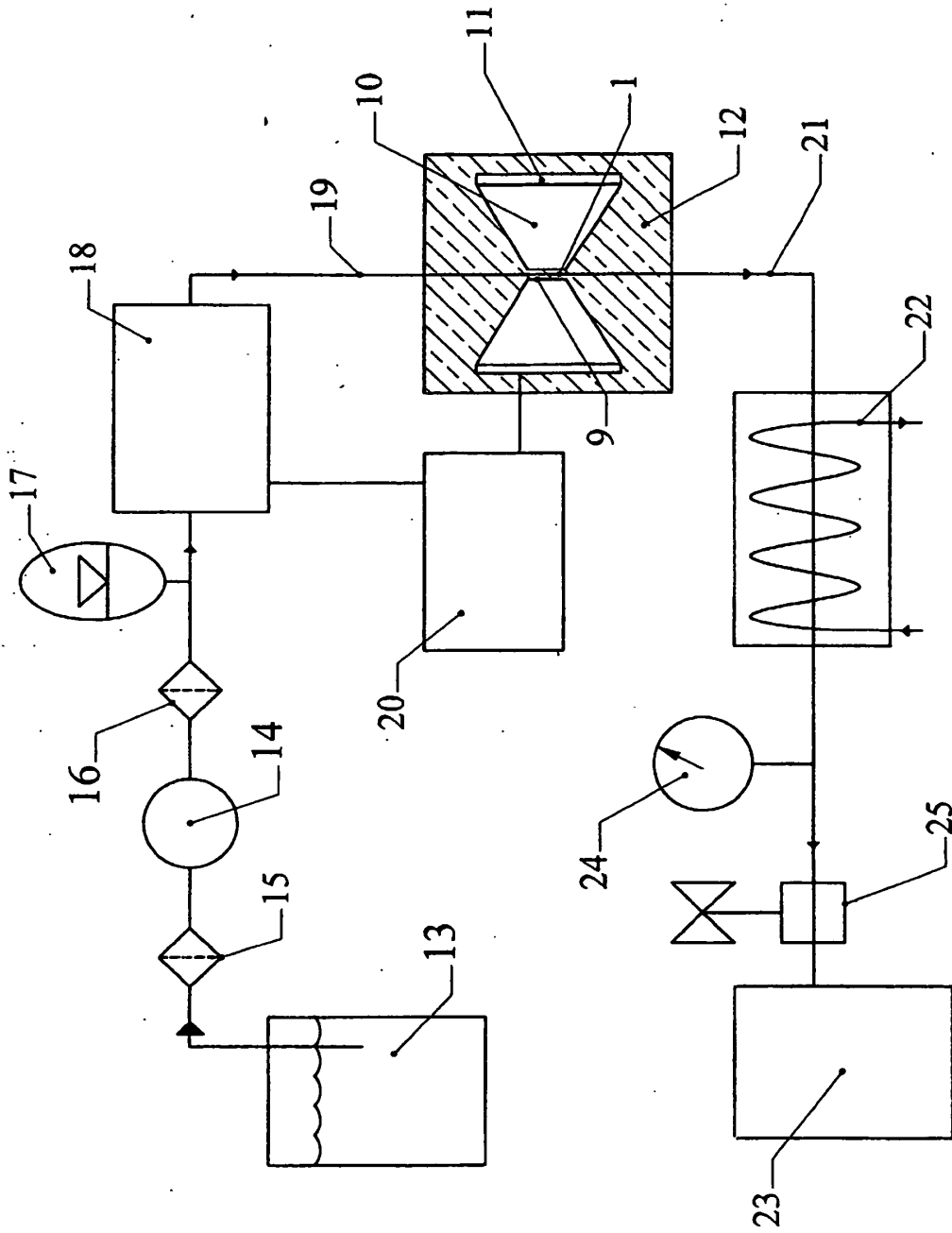


Figure 1

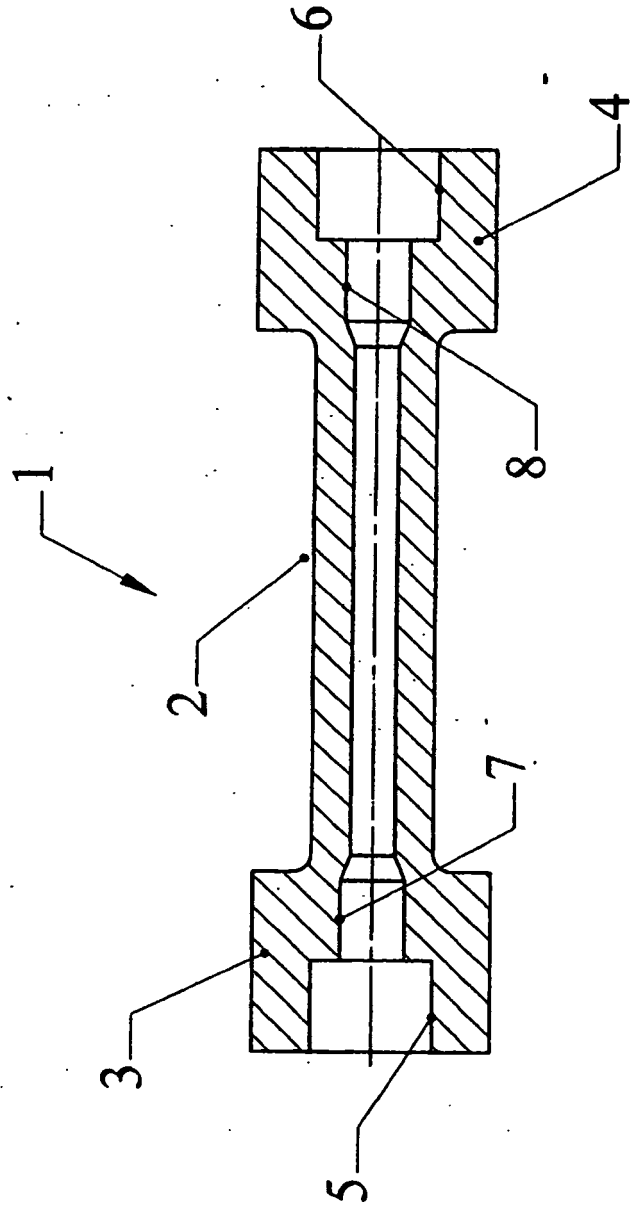
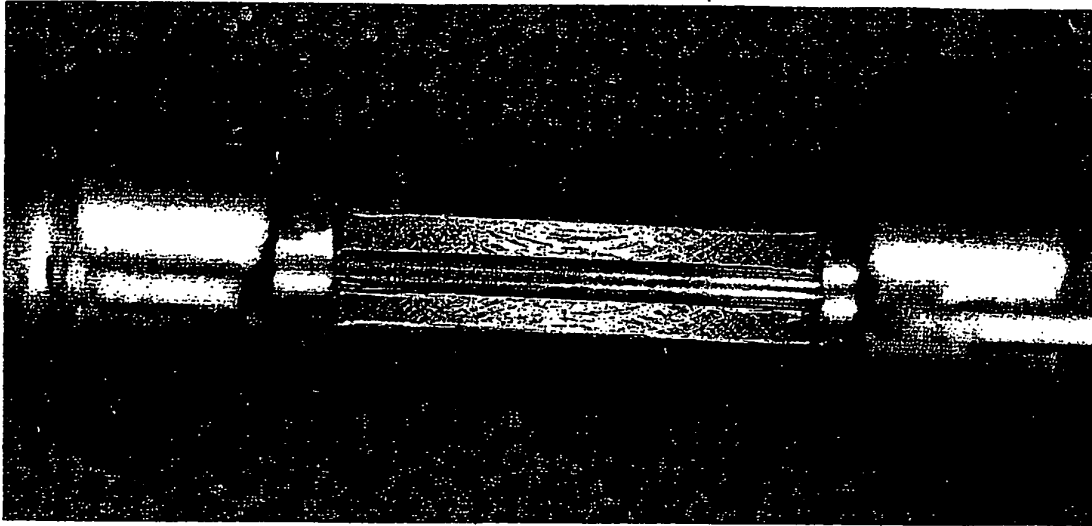
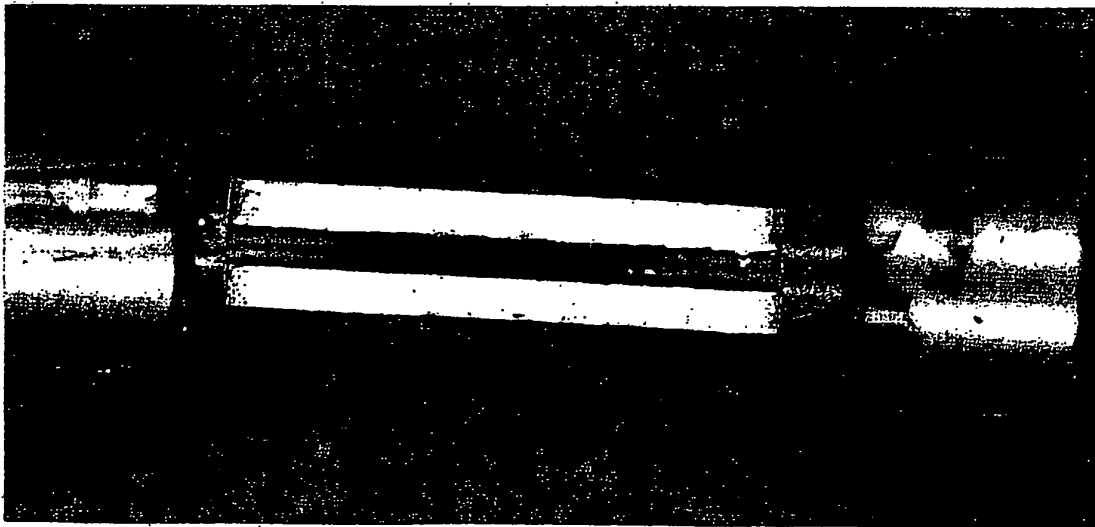


Figure 2



(A)



(B)

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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